

EXAMPLE 1

One of the major models for environmental site assessment based on soil properties was developed by the Environmental Protection Agency (EPA) using DQA soil property default values to estimate soil contamination nationwide. Five assumptions anchor the EPA criteria for soil-screening for contamination in the Superfund program in the SSL MINTEQ modeling effort (p.156, Section 5.4.4, chemical specific parameters - TBD):

- The system is assumed to be at equilibrium. (Metal concentrations in pore water may be less than predicted by the model.)
- Redox potential is not considered. (The oxidation state that most enhances redox-sensitive metal mobility is modeled separately defining metal Kd values.)
- Potential sorbent surfaces are limited to metal adsorption to FeOx and solid organic matter in the system. (Model under predicts sorption for soils with significant amounts of clay or carbonates).
- The available thermodynamic database is limiting due to complexity of metal behavior. (Metal availability may be more or less than predicted).
- Metal competition is not considered and resulting higher dissolved metal concentrations are not included in the model. (Model is significant only at metal concentrations much higher than the Soil Screening Levels.)

METHODS

- STATSGO and SSURGO: Search database for EPA default levels (DQA) for soil properties and evaluate the compatibility of NRCS data on soil-landscape units and their components with the EPA site model and its assumptions.
- NSSL: Review data from preliminary urban soil studies for compatibility with the EPA Soil Screening thresholds as an example of site-specific data compared to soil-landscape units. Site-specific or single land-use studies may omit accompanying soil properties needed to characterize the dynamics of that soil system.

DISCUSSION

The Soil Survey database (STATSGO) for loam surface layers did not match the default values for bulk density, organic matter, pH, or water content. Bulk densities consistently were lower than 1.5g/cm though measured wet instead of dry. Organic carbon contents and pH were consistently higher than the default and water contents were lower than the default. This data reflects the non-risk agricultural condition of many surface soils in the USA and provides a useful baseline against which to evaluate disturbed and urban soils.

A similar search of SSURGO surface layers for a soil survey area in eastern Massachusetts found fine sandy loam surface layers instead of loams. Similar relationships were found as three of the soil properties were outside of the risk default ranges. pH was consistently low and within the risk range for these soils, suggesting that poor soil management leading to compaction and depletion of organic matter could increase the risk level or soil properties.

Urban soils sampled for metal content were also characterized for soil properties used in EPA soil screening. Bulk density and water content (0.33 kPa) were not measured for these soils. Organic carbon and pH were higher than EPA soil screening defaults. Urban gardens on these soils currently are low risk due to soil properties but soil management is essential to avoid increased risk. Each garden would require an evaluation of landscape relationships, actual plant uptake, and the health of target consumers to quantify the actual dietary risk.

Urban Soil Garden Characterization Protocol (draft)

Research needs for urban gardens based on EPA SSL thermodynamic assumptions:

- Measure changes in contaminant phases over time to avoid the assumption of equilibrium. Include interactions of soil properties, plant uptake, and contaminant phase (adsorbed or dissolved). Look for adsorption/desorption rate limits, and changes in the components of mass balance in the soil solid phase or liquid phase.
- Monitor contaminant phases across seasonal soil water contents. Consider redox potential by obtaining reliable field measurements of oxidation reduction potential (Eh), major biological agents, and concentrations of redox-sensitive metal species.
- Describe metal adsorption to natural sorbents such as clay and carbonate minerals in addition to iron oxides and solid organic matter. Determine what percentage of soils have significant amounts of clay and carbonate sites for contaminant adsorption.
- Capture some of the complexity of metal behavior with thermodynamic data from within the soil system (temperature, heat flux, porosity and dynamic aggregation).
- Consider metal competition among the common contaminants in urban sites and compare to a simplified system for parsimony.

EPA Soil Screening for Contamination Applied to Soil Survey Data

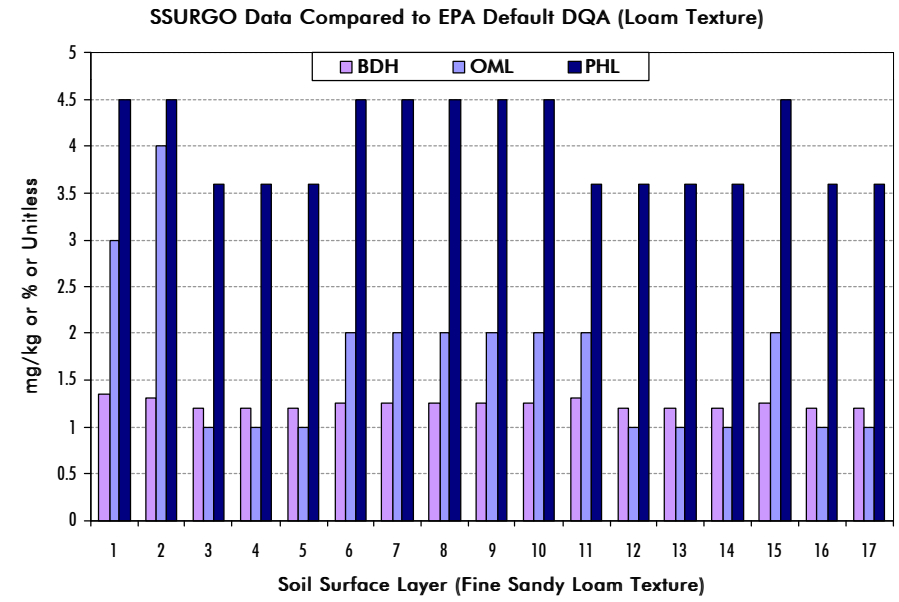


Table 1. EPA identified DQA soil properties for soil screening based on loam soil texture (Table A-2, U.S. EPA 1996).

Soil Property	DQA	Risk Pathway
Dry soil bulk density	1.5 kg/L	INH (inhalation)
Soil porosity	0.43	
Volumetric soil water content	0.15 ml/ml 0.30	INH (inhalation) MTG (migration)
Volumetric soil air content	0.28 ml/ml 0.30	INH (inhalation) MTG (migration)
Soil organic carbon	0.6 % 0.2 %	INH (inhalation) MTG (migration)
Soil pH	6.8	to determine K _d (metals) & K _{oc} (ionizable organics)
Modal soil aggregate size	0.5 mm	INH (used for windspeed)
Threshold windspeed @ 7m	11.32 m/s	INH (uses roughness ht. 0.5 cm - open terrain)

Table 2. Comparison of EPA DQA soil screening with measured values of critical soil properties in soil survey database.

Soil DQA content	Bulk density ¹ > 1.5 gcm-3	Organic carbon ² < 0.02 - 0.06%	pH < 6.8	volumetric water > 30%
A. STATSGO	32.4%	0.5%	1.4%	0.2%
B. SSURGO	0%	0%	5.5%	0%
C. Urban Soils	n/a	0%	0%	n/a

¹ Bulk density measured moist for soil survey, dry for EPA.

² Organic carbon was calculated as (organic matter) / 1.72.

- NRCS STATSGO data for 15091 component records (loam texture throughout the USA). Source of data: NRCS map unit database in 9/99.
- NRCS SSURGO data for 18 surface layer components with fine sandy loam texture (Norfolk and Suffolk Counties, Massachusetts). Source of data: NRCS website in 9/99.
- Selected urban soil data characterized for metal content as part of soil survey. Source of data: NRCS National Soil Survey Lab 1996.

SOIL SURVEY A Nationwide Resource & an Underused Environmental Screen Tool

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ABSTRACT

The National Cooperative Soil Survey has provided 100 years of soil inventory, measurement, and evaluation as of 1999. Soil surveys have been conducted for urban centers and military lands in addition to the privately owned lands of the USA. Current applications of soil survey addressed by USDA-NRCS scientists range from contaminated soils and heavy metal analysis to traditional work in range, forest, and agronomic soils. Currently, the NRCS maintains several databases with digital soil survey data -- including a database that contains data on more than 25 physical and chemical properties for more than 20,000 soils that have been sampled in the United States. Preliminary guidelines and protocols for addressing contaminated soils in urban soil survey will be presented. Finally, examples of ongoing projects and growing linkages between soil survey and environmental risk assessment will also be presented.

INTRODUCTION -- Federal agencies practice Environmental Justice for all citizens

Soil contamination is an environmental concern that directly affects some citizens more than others. The empowerment of concerned citizens is one of the services provided by the federal government to help communities and individuals make wise land use decisions. The environmental decisions are thus supported by scientific research, so that neither economic hardship nor educational disadvantage limits the availability of technical assistance.

The Natural Resources Conservation Service (NRCS) is a Federal agency that works in partnership with the American people to conserve and sustain our natural resources on private lands. The USDA-NRCS environmental vision is that "The next increment in land stewardship will come about when rural and urban residents jointly accept the reality that everybody is somebody's neighbor, that shared responsibility is the key. A search for consensus then becomes the foundation for effective land stewardship in communities and watersheds across the country" (USDA-NRCS, 1996). NRCS also has a federal mandate for urban conservation and technical assistance as summarized in various laws and statutes.

Environmental Justice is a driving force for environmental stewardship that links federal agencies and community groups. The Environmental Protection Agency (EPA) defines Environmental Justice as "the fair treatment of people of all races, cultures, and incomes with respect to the development, implementation, and enforcement of environmental laws, regulations, programs, and policies." The overall EPA mission is "to protect human health and the environment". The EPA Brownfields Economic Redevelopment Initiative (BERI) targets assistance to cities that have "identified contaminated sites offering the greatest opportunity for remediation and economic activity" (Bartsch and Collaton, 1997).

In addition, through the USDA Office of Community Development and a number of USDA agencies including Rural Development, the Natural Resources Conservation Service, and the Forest Service participate and contribute financial and technical assistance to the Rural Empowerment Zones and Enterprise Communities Initiative. This program has empowered rural citizens to become active participants and stakeholders in planning their community's economic and social growth (USDA - Rural Development, 1998).

OBJECTIVES

- Provide links to laboratory data that is integral to soil survey (but often over-shadowed by the soil-landscape paradigm).
- Present preliminary guidelines and protocols for addressing contaminated soils in urban settings using soil survey. Show two examples of ongoing projects and growing linkages between soil survey and environmental risk assessment.
- Define a quantitative relationship between urban soil properties and food quality that helps to estimate dietary risk from contaminated garden soils.

RESEARCH AND NETWORKING NEEDS

Collaboration

- Growing linkages often revolve around funding sources
- Develop a trust between grassroots groups and government agencies
- Among professionals in different disciplines
- Agencies (NRCS, ARS, EPA, USGS, USFS, local and regional)
- Professional societies with new journals (AEHS, SSSA)
- Develop a web-based information system for technology transfer
- Develop an audit for environmental justice and sustainable communities to identify research and technical needs of eco-cultural systems

Participation in International Workgroups

- International Committee for Anthropogenic Soils (ICOMANTH)
- Soils of Urban, Industrial, Traffic, and Mining Areas (SUITMA - IUSS)

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A Nationwide Resource & an Underused Environmental Screen Tool

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Research Protocol Tailored to Urban Soils

- Urban soil quality minimum data set common across groups
- Field sampling guides for community groups of non-scientists
- Consensus on schemas for taxonomy based on estimated behavior

Field Trials to Improve Estimates of Urban Soil Behavior

- Expanded sampling of urban soils to refine defaults in models
- Build database of site-specific data with links to landscape model
- Incorporate data on international urban soils

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Cadmium Dynamics in Soil Leading to Dietary Risk from Lettuce

Soil contamination from heavy metals is a potential problem on many urban soils. Many community gardens are established on sites unsuitable for other purposes and that may be contaminated with a high content of heavy metals. There is little information available to urban residents to assist them in estimating relative dietary risk for different crops on different soils with similar contents of heavy metals. Soil survey is an effective tool for investigating the spatial distribution of contaminants at potential garden sites and to provide interpretations of critical soil properties (Scheyer, 1998a).

The kidney diseases associated with Cadmium overdose appear to selectively impact pregnant women, women after multiple childbirth, people with insufficient nutrition (insufficient dietary iron, zinc, and calcium), and older people. These citizens are candidates for environmental justice as they may also suffer disproportionate environmental risk due to their low economic and socio-political status in some urban areas (Chaney and Ryan, 1994).

Lettuce is a good indicator crop for cadmium studies because it accumulates the metal in the edible portion, it can be ready for consumption in as few as 28 days after planting, and it is grown in many countries at low cost in both kitchen and community gardens (Lehoczky et al., 1998a).

Dietary risk from urban garden soils results from combinations of soil properties and from bioavailability of contaminants, rather than from total elemental concentrations. The process of soil aggregation may sequester heavy metals and therefore reduce the risk of dietary consumption. Metals are known to form cation bridges for water-stable microaggregates and form complexes with charged organics and inorganics in addition to clay active surfaces in the soil (Scheyer 1998b).

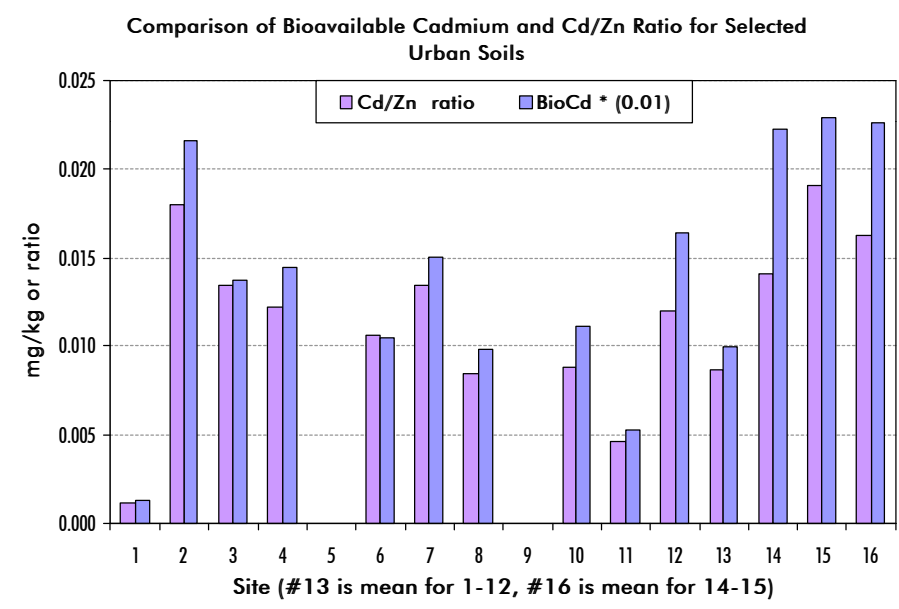


Table 4. Cadmium (Cd) measurements to estimate dietary risk in urban soils.

Site #	Cadmium (mg/kg)	Zinc (mg/kg)	Cd/Zn Ratio	¹ Bioavail. Cadmium	Depth (cm)	Organic Carbon	pH (CaCl ₂)
1	0.2	179.5	0.001	0.13	0-15	3.47	6.4
2	3.3	183.1	0.018	2.16	15-30	1.90	7.2
3	2.1	156.5	0.013	1.38	0-15	2.82	7.2
4	2.2	180.1	0.012	1.44	15-30	1.43	7.3
5	0	162.1	0	0	0-15	2.73	7.1
6	1.6	150.6	0.011	1.05	15-30	1.69	7.3
7	2.3	171.2	0.013	1.51	0-15	2.54	7.3
8	1.5	178.1	0.008	0.98	15-30	2.16	7.4
9	0	166.8	0.000	0	0-15	2.31	7.2
10	1.7	101.9	0.009	1.11	15-30	1.54	7.4
11	0.8	172.1	0.005	0.52	0-15	3.01	7.1
12	2.5	208	0.012	1.64	15-30	1.72	7.3
13 (mean)	1.52	175	0.009	0.99	0-30		
14	3.4	241.1	0.014	2.23	0-15	1.95	7.2
15	3.5	183.5	0.019	2.29	15-30	1.24	7.3
16 (mean)	3.45	212.3	0.016	2.26	0-30		

* Cd/Zn ratio > 0.015 (Chaney and Ryan, 1994)

¹ Bioavailable Cd = total Cd (65.5%) (Lehoczky, et al., 1998a)

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EXAMPLE 2

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METHODS

- NASIS Fuzzy Logic: Define relationships between soil properties that may be used in a draft interpretation table for dietary risk assessment using soil survey data and thresholds from the literature.
- Sample preparation and lab methods for cadmium and zinc analysis and for calculating bioavailable cadmium are detailed in the literature. Correlation of total metal contents by two methods (ICP vs. XRF) may affect interpretations.
- Soil-cadmium dynamics also involve cation exchange capacity (CEC) (Chaney and Ryan, 1994), and those soil properties used in the EPA soil screening guidance (bulk density, pH, organic carbon content, water content, modal aggregate size). pH is measured three ways (in KCl, CaCl₂, or H₂O) and organic carbon is measured in two ways (total carbon and Walkley-Black) for the urban soil data in these cadmium studies.

DISCUSSION

Cadmium-Zinc ratios in two urban gardens demonstrate the advantage of a survey approach over a random sampling approach.

In the first garden the mean ratio (site #13) is below the threshold of 0.015 for risk that was cited by Chaney and Ryan (1994). The relative location and size of sites within the garden was not recorded but would be available from a soil survey. The risk at sites above the threshold may be diluted during harvest unless each site is large enough to produce a separate package of produce.

Landscape and soil-forming factors, with anthropogenic subfactors, may explain the location of the risk areas in the gardens. The soil survey approach would identify these factors and give clues to possible translocation of metals within the gardens.

The second garden has a mean Cd/Zn ratio above the threshold and appears to have risk throughout. In this case the mean ratio is representative of the garden overall, but masks certain areas of higher risk. Under current soil management, pH and organic carbon levels are high enough to minimize risk.

Bioavailable cadmium, calculated as 65.5% of total cadmium (Lehoczky, et al., 1998b), showed trends similar to those of the Cd/Zn ratio in the two gardens. Sites with Cd/Zn ratio of 0.014 or higher showed bioavailable cadmium above 2.00 mg/kg and total Cadmium above 3 mg/kg. Sites with Cd/Zn ratio just below 0.015 but with total cadmium between 2 and 3 mg/kg had bioavailable Cd around 1.5 mg/kg.

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